DOCUMENT RESUME

ED 129 560 SE 019 029

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TITLE An Investigation to Empirically Determine Which Instructional Procedures Produce Optimum Student Growth.

PUB DATE Mar 75

NOTE 24p.; Paper presented at the annual meeting of the National Association for Research in Science Teaching (48th, Los Angeles, California, March 17-20, 1975); Contains small print in Figures

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.

DESCRIPTORS *Educational Research; *Instruction; Learning Activities; Science Activities; Science Education; *Scientific Attitudes; Scientific Concepts; *Secondary Education; Secondary School Science; *Teaching Procedures

IDENTIFIERS Research Reports

ABSTRACT

This study involved the search for statistically significant linear and curvilinear (optimal) relationships between assessed student perceptions about classroom instructional procedures and pre- posttest changes in students' understanding of science concepts, attitudes toward science, and development of interests in science. The nineteen teachers and thirty-eight science classes involved in the study also participated in a research plan that included the administration of several instruments in a pre- posttest design during the academic year. Data were collected using: (1) concept-process tests, (2) the Science Classroom Checklist (SCACL), (3) the Silance and Remmers Interest Scale, and (4) an instrument to measure student attitudes toward science and scientists (BATSS). For this study, the Instructional Activities Instrument was developed, piloted, and administered near the end of the year. A direct/indirect score on this instrument was compared to corresponding pre- posttest change scores as measured by the other four instruments. A linear relationship was found between student attitude toward science as a subject and teacher direct-indirectness, and certain instructional methods were found to lose favor with students if frequently used. (Author/MH)

AN INVESTIGATION TO EMPIRICALLY DETERMINE WHICH INSTRUCTIONAL PROCEDURES PRODUCE OPTIMUM STUDENT GROWTH

A Discussion Paper
for
NARST, Los Angeles
March, 1975

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Introduction

The need to empirically determine which combination of lecture, discussion, highly structured, loosely structured or direct-indirect oriented teaching produces optimum student growth in science classes has been recognized by researchers such as O. Roger Anderson (1971) but has been actively pursued by very few. Undoubtedly, there are many reasons for this. Certainly the accessibility of the proper statistical procedures and computing equipment can pose problems to the researcher but the reasons may be more philosophical. Researchers have been drawn in large numbers toward establishing the superiority of one program over another and have not asked or tried to determine at what point or level features such as teacher use of inquiry interaction strategies, laboratory based activities and open-ended investigations produces greater student knowledge of, and more positive attitudes toward, the subject. They have also failed to ask if further increases in the use of such procedures lead to decreased subject matter growth and less favorable attitudes. These ideas are considered in the following paper. First, there is a brief summary of how optimization theory has been considered by educators and then a description of a study to Empirically Determine Which Instructional Procedure. roduce Optimum Student Growth.

Optimization Theory and Science Education

The mathematicians Wilde and Beightler (1967) have described optimization as a theory which encompasses the quantitative study of optima and methods of finding them. The statisticians Bellman and Dreyfus (1962, p. 15) give the following definition:

> An optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision.

Optimization theory is now being applied in fields as diverse as biology (Rosen, 1967 and 1971), psychology (Cronbach and Gleser, 1965) and engineering (Aris, 1961). In education, however, optimization theory has received only passing attention and the terms optimizing, optima and optimum are used in a somewhat confusing fashion in at least two ways: one mathematically rigorous; the other more informal but perhaps more relevant to current educational research practices. A feeling for the range in definition and usage in education is perhaps best achieved with reference to two papers; one called "Models for Optimizing the Learning Process" by Groen and Atkinson (1966), and another titled "Optimum Teacher-Pupil Interaction for Pupil Growth by Robert S. Soar (1968).

In the more mathematically rigorous of the two papers, Groen and Atkinson (1966) outline a common instructional paradigm concerning programmed learning and suggest a notation which allows the paradigm to be restated as a multi-stage decision process with an explicit mathematical learning model embedded in it. They applied these procedures in an effort to avoid research techniques which

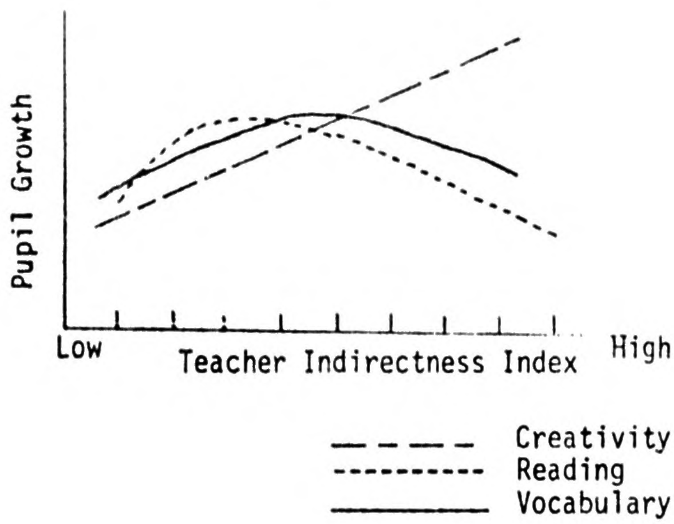
led many other workers investigating programmed learning to insignificant and conflicting results. Basically, these workers had two goals: 1) to provide an explicit statement of the problems of optimal instruction in the framework of multi-stage decision theory and, 2) to indicate, using dynamic programming as an example, how optimization problems can be solved in practice (Groen and Atkinson, 1966).

By contrast, Soar (1968) used data from interaction analysis research and pupil attitude and content changes in a way which allowed non-linear or curvilinear relationships to be identified, if they existed. He is, then, one of the first researchers in education to employ optimizing principles to classroom observation data. Optimum as used by Soar and in this study is defined through the use of polynominal regression analysis using the BMD 05R computer program (Dixon, 1968). (This program plots successfully higher degree equations and computes an F value for each.) Soar apparently did not derive his hypothesis directly from the mathematical concepts of optimization but rather, was influenced by the learning psychologists' Castaneda, McCandless and Palermo (1965) who had previously found evidence supporting non-linear relationships between learning and anxiety levels in children.

Soar's data supporting non-linear relationships was collected during an extensive study of fifty-four classrooms, grades three through six, in four elementary schools in Central South Carolina over a two year period. The results he obtained from the initial analysis in this study were difficult to interpret, especially when only simple linear regression lines were used. This led him to re-analyze the data in search of the optimal relationships. The results of the re-analysis using a BMD (Biomedical Computer Program) 05R Polynominal Regression program (Dixon, 1965) specifying the fitting of a

two-degree polynominal are most succinctly summarized by the graph which follows:

FIGURE 1: Teacher Indirectness Related to Pupil Growth



He also believes his results indicate that the effective teacher must be able to shift style as he shifts objectives (Soar, 1968, p. 278). He suggests that direct control and a non-supporting climate (as measured by Flanders) induce stress on the pupil and that optimum level of stress or anxiety shifts as the task complexity changes. In another study Coates (1966) found similar relationships between pre and post attitude data and degree of teacher acceptance (as measured in Flanders' category 3-3).

An Investigation to Empirically Determine Which Instructional Procedures Produce Optimum Student Growth

The primary objective of this study was to empirically determine which combination of lecture, discussion or direct-indirect oriented teaching produce optimum student growth. The study involved the search for statistically significant linear and curvilinear (optimal) relationships between assessed student perceptions about classroom instructional procedures and pre-post test changes in student 1) understanding of science concepts and processes, 2) attitudes toward science and scientists and 3) development of interest in science as a classroom subject. A secondary objective was to develop an instrument to assess student perceptions of and attitudes toward the frequency with which teachers use a variety of instructional moves and techniques.

Methodology and Design

Nineteen teachers and thirty-eight science classes (two for each teacher) were involved in the study. All teachers were participants in a NSF sponsored College School Cooperative Science Earth Science program (CCSSP) conducted for teachers from the north central Ohio region. This study was part of a comprehensive research plan which included the administration of several instruments in a pre-post test design during the academic year. Data was collected using: A) concept-process tests, B) the Science Classroom Checklist (SCACL), C) the Silance and Remmers Interest Scale and D) an instrument to measure student attitudes toward Science and Scientists (BATSS). As part of this evaluation program, Disinger (1971) studied (1) the relationships that existed among student cognitive and affective areas as related to a number of teacher variables and (2) the relationships among class characteristics and student and criterion variables.

The developed Instructional Activities Instrument was piloted and then administered near the end of the year. The decision to develop an instrument to measure student attitudes toward, and perceptions of, the frequency with which teachers use certain instructional procedures was spurred by the need for an instrument which would:

1) be based upon the theories used in interaction analysis observation classification systems: this would allow some comparisons between this and interaction analysis studies such as those completed by Coates (1968).

2) be workable: some of the questions raised might have been answered after collecting extensive interaction analysis data but it would have been impossible to do this for 38 classes scattered over a wide geographic area.

3) be able to assess the complex interrelationships between student attitudes and perceptions: no instrument existed to measure these relationships.

The developed instrument contained paired perception and attitude items. The conceptual basis for the perception items was built around the discussion of instructional strategies by Hough and Duncan (1970). These workers describe four basic instructional strategies: 1) interactive strategies, 2) independent strategies, 3) direct strategies, and 4) group strategies. This conceptual framework was selected because of Hough and Duncan's detailed description of moves and tactics and the way these are built into strategies.

A parallel "paired" attitude item was constructed for each perception item. These items were designed so that the student could select one distracter along a five point continuum ranging from "more often than he (the teacher) does now" (distracter "1") to "as often as he (the teacher) does now" (distracter "3") to "not as often as he (the teacher) does now" (distracter "5").

This somewhat unorthodox design was devised because of the investigator's feeling that educational researchers have too frequently reduced data collecting instruments to simplistic either/or dichotomies which fail to reflect the intricate

complexities of the instructional situation. Relationships between pupil outcomes, teacher behaviors and instructional strategies are best viewed in a relativistic framework (in this instrument the student's response on the attitude item is given relative to his response on the perception item).

Scoring on this instrument was accomplished in a way which allowed a direct-indirect score to be determined from student responses in each of the thirty-eight classes involved. The direct/indirect score was then compared with corresponding pre-post change scores as measured by each of the other instruments used to assess student growth. A brief description of each of the instruments used to collect this data is given below:

Concept-Process

An instrument designed to measure major science concepts and processes was developed by Disinger (1971) around the seven basic conceptual and the five major items in the processes of science identified by the National Science Teachers Association (1964).

Science Classroom Activity Checklist (SCACL)

SCACL is a modified form of the Kochendorfer and Lee checklist (Kochendorfer, 1967). Sagness (1970) extensively used this instrument with pre-service science education students at The Ohio State University. Two forms of the instrument were used in this study: a teacher form and a student form.

Scale for Measuring Attitude Toward Any School Subject (Interest Scale)

In 1934 Silance and Remmers developed a forty-five item scale to measure attitude toward school subjects. Later, (Remmers, 1970) developed a seventeen item form to measure attitude toward any school subject. This was modified slightly so that it referred specifically to the science classrooms in this study.

The Beliefs and Attitudes Toward Science and Scientists (BATSS)

BATSS were measured using a modified form of an instrument developed by Champlin (1970). Champlin was concerned with testing student beliefs and attitudes toward science and scientists. He accomplished this by developing a thirty-three item belief and thirty-three item evaluative scale. Scoring on the belief items was detemined by the number of "correct" responses to the belief items while belief and evaluative items were paired. In order to obtain an attitude score, a simplified scoring system was later developed by Disinger (1971) during the present study.

Data collected with these instruments was used in the analysis with the BMD 05R Polynominal Regression program to see if optima existed and to determine if significant linear or curvilinear relationships could be found. On the first run, the program was set to compute F values for first, second, third, and fourth degree equations, then re-run so a computer drawn graph would be produced showing the best fitting line. Attitude and perception scores were also compared using the BMD 05R Polynominal Regression program and the results used to tentatively identify "fragile" and "durable" instructional moves and techniques.

Results and Conclusions

In the first phase of the analysis, seven tests were made comparing the teacher direct-indirectness score as computed from the Instructional Activities Instrument with student growth variables as measured by pre-posttest change scores on several instruments. These tests were made with the BMD 05R Polynominal Regression Program and although the results did not show a significant curvilinear relationship, a significant ($p = .05$) linear relationship between student attitude toward the subject as measured by the Silance and Remmers Scale and teacher direct-indirectness was found. This information is summarized in Table I and

on figures 2 through 8 in the appendix of this paper.

TABLE I

POLYNOMINAL REGRESSION ANALYSIS COMPARING THE COMPUTED I/D SCORES FOR EACH CLASS WITH THE CHANGE SCORES

Variables	Best Fitting Line (Degree of Equation)	F Value to Enter	Pearson Product Moment Correlation Coefficient
Concept	3rd	0.64	0.0617
Process	1st	2.79	0.2683
Concept-Process	1st	1.62	0.2077
SCACL	3rd	0.86	0.0370
Attitudes (BATSS)	1st	1.05	0.1684
Beliefs (BATSS)	1st	1.54	0.2031
Interest	1st	4.15*	0.3215

n = 38 classes
*$p \leq .05$
**$p \leq .10$

The second phase of the analysis involved using the BMD O5R Polynominal Regression Program to identify the nature of the relationship which existed between the fifteen paired perception and attitude items. The results of some of these tests are summarized in Table II. This table was constructed by ranking the item pairs based upon the Pearson Product Moment Correlation Coefficient on the "more" tests. This was done in order to gain further insight into the complex relationships which exist between the paired perception and attitude items. In this table, the fragile items occur at the top while more durable instructional moves and techniques are found at the bottom. Here fragile and durable refer to

TABLE II

INSTRUCTIONAL MOVES AND TECHNIQUES RANKED ACCORDING TO CORRELATION COEFFICIENTS: "MORE"

Paired Items	Hypothesis Number	Mean Frequency of Perception Item*	Pearson Product Moment Correlation Coefficient	Description of Item
25 x 26	I-M	1.50	-0.5688	filmstrips
1 x 2	I-A	2.55	-0.5392	student interaction discussion
27 x 28	I-N	1.40	-0.3423	films, movies
19 x 20	I-J	1.03	-0.2673	carrels, booths
3 x 4	I-B	2.40	-0.2579	reflecting questions
15 x 16	I-H	2.24	-0.2414	working from textbook
23 x 24	I-L	2.29	-0.2332	step-by-step direction in lab
5 x 6	I-C	3.03	-0.2161	general questions
21 x 22	I-K*	2.51	-0.1133	lecturing
11 x 12	I-F*	1.80	-0.0395	independent student work
7 x 8	I-D*	2.16	-0.0270	specific questions
9 x 10	I-E	2.26	+0.0407	discussion, debate
29 x 30	I-O*	1.14	+0.2001	direct answers to student questions
17 x 18	I-I	1.25	+0.2096	contracts
13 x 14	I-G	1.29	+0.2925	reference materials

*These items had insignificant optimal relationships (the F value was highest for a second, third, or fourth degree equation).

the ability of the described instructional move or techniques in the item to be used very frequently while still retaining favor with the students.

Findings in this portion of the study suggest that certain instructional procedures are "fragile" and rapidly lose favor with students if used frequently by the teacher, while others are more "durable" and can be used frequently while retaining positive student opinion. Among the fifteen instructional techniques and procedures described on the Instructional Activities Instrument, the use of filmstrips, discussion and debate, and films or movies were more "fragile" than the others.

Discussion and Conclusions

The techniques used in this study illustrate one way data can be collected and statistically analyzed so researchers can look beyond simple linear correlations in order to determine if curvilinear (optimal) relationships exist. The design also includes a procedure for collecting and quantifying student perceptions and attitudes about the frequency with which certain instructional procedures are used instead of leaving these decisions entirely to teachers and curriculum designers.

In this study an optimal relationship was said to exist when a significant second, third, or fourth order equation was identified by the BMD Polynominal Regression Program. This, of course, constitutes an operational definition of an optimum procedure. This definition provided an excellent way to test hypothesis but other statistical procedures may hold equal potential. Education data is often scattered (see figures 2-8) and even in a comprehensive study such as this where 38 classrooms and 19 teachers were involved, there is naturally some concern about the effect of one or two spurious points on curvilinear lines. In this study the BMD 05R program was employed more than 50 times. This

included the seven plots of I/D scores and student growth measures included in the appendix and more than 45 tests of the interrelationships between attitude and perception items. Second, third and fourth order equations were frequently found to best fit the data, but F values were generally low. A secondary outcome, however, was the procedure used to tentatively identify "fragile" and "durable" instructional procedures. This technique is also an optimizing procedure and may be considered as an alternative way to empirically determine optimimum relationships.

APPENDIX

I/D SCORE AND GROWTH VARIABLES PRODUCED USING THE BMD 05R POLYNOMINAL REGRESSION PROGRAM

I/D Scores

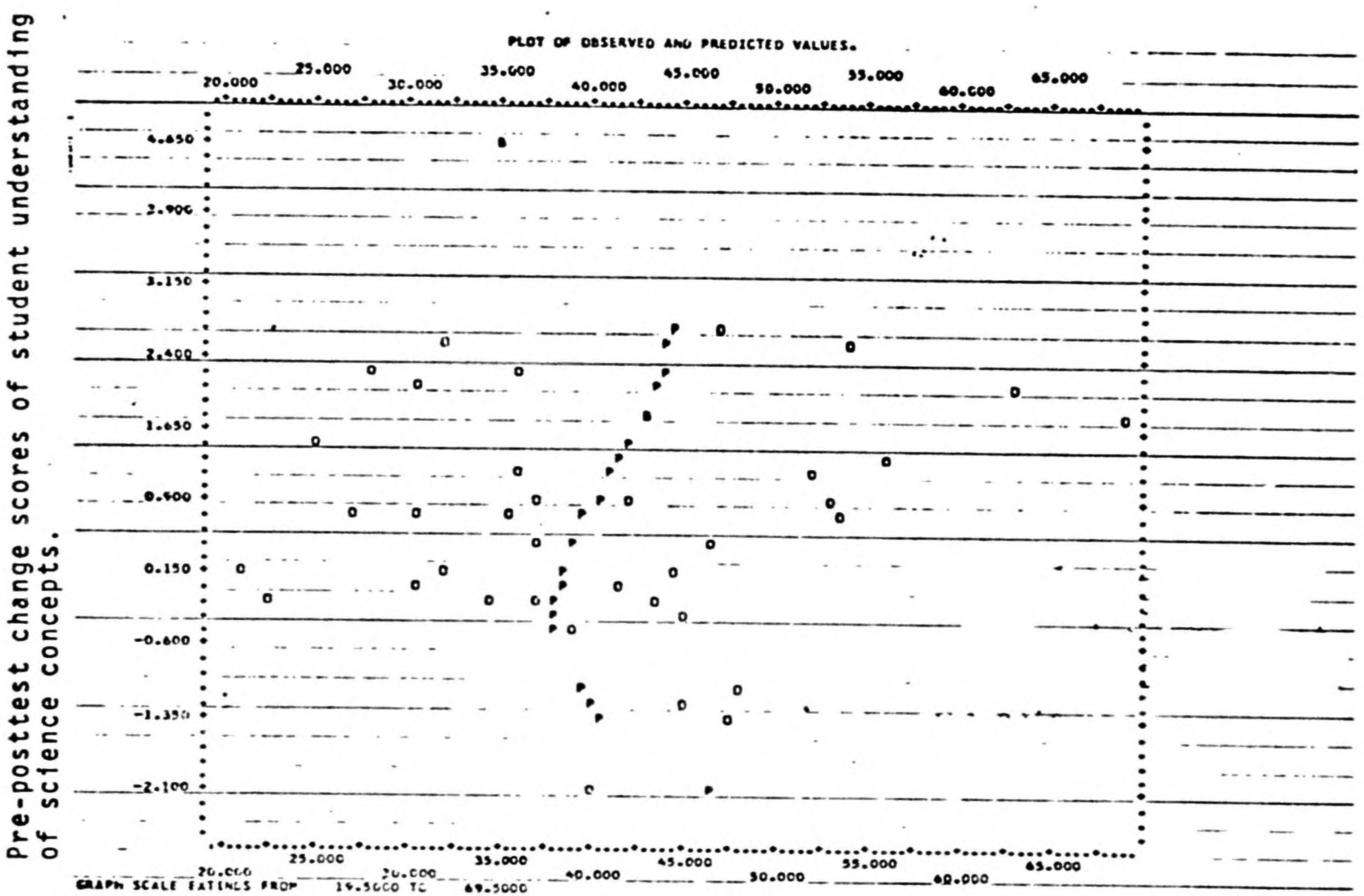
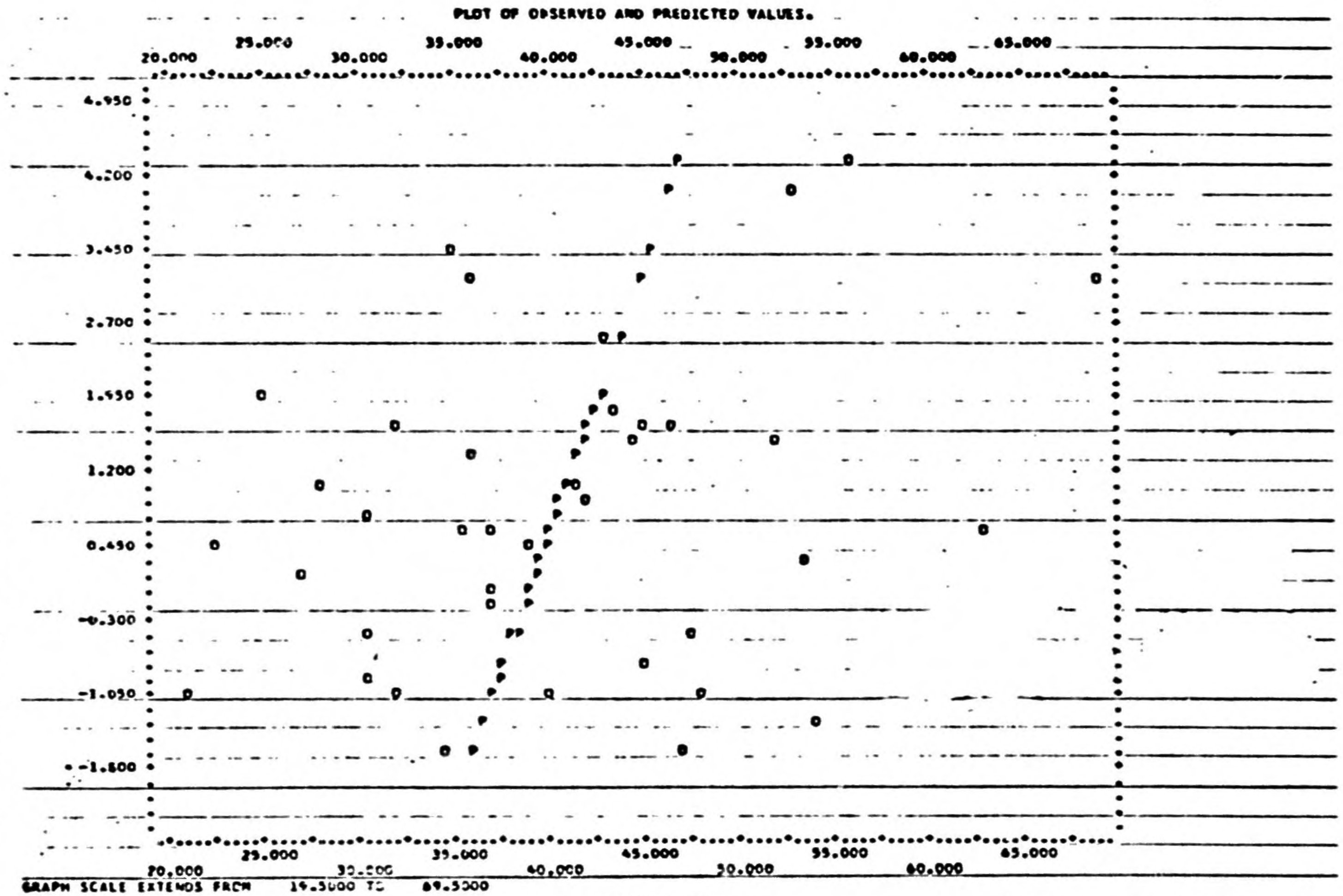


FIGURE 2

I/D Scores



Pre-posttest change scores of student understanding of science processes.

FIGURE 3

I/D Scores

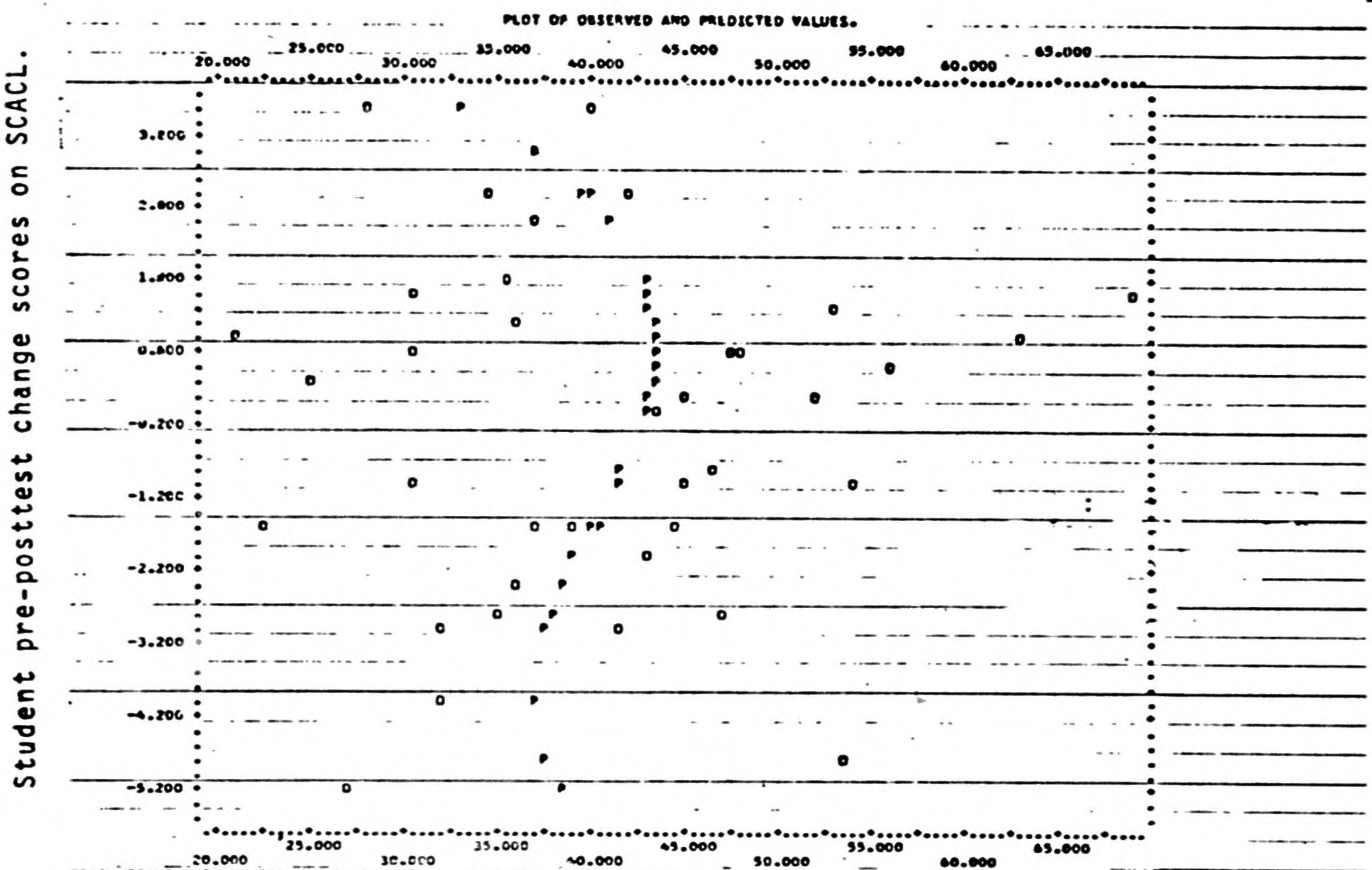


FIGURE 4

I/D Scores

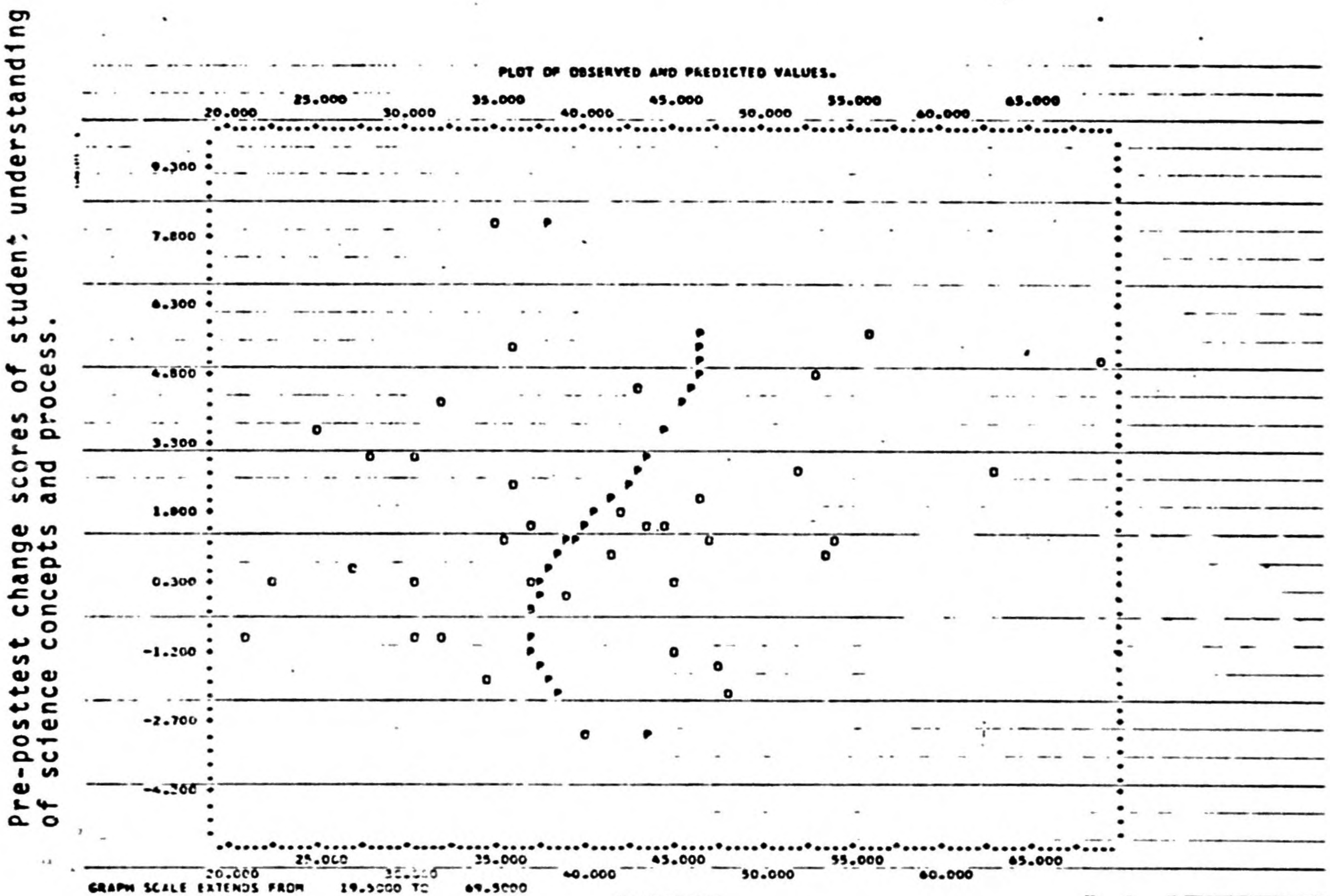


FIGURE 5

I/D Scores

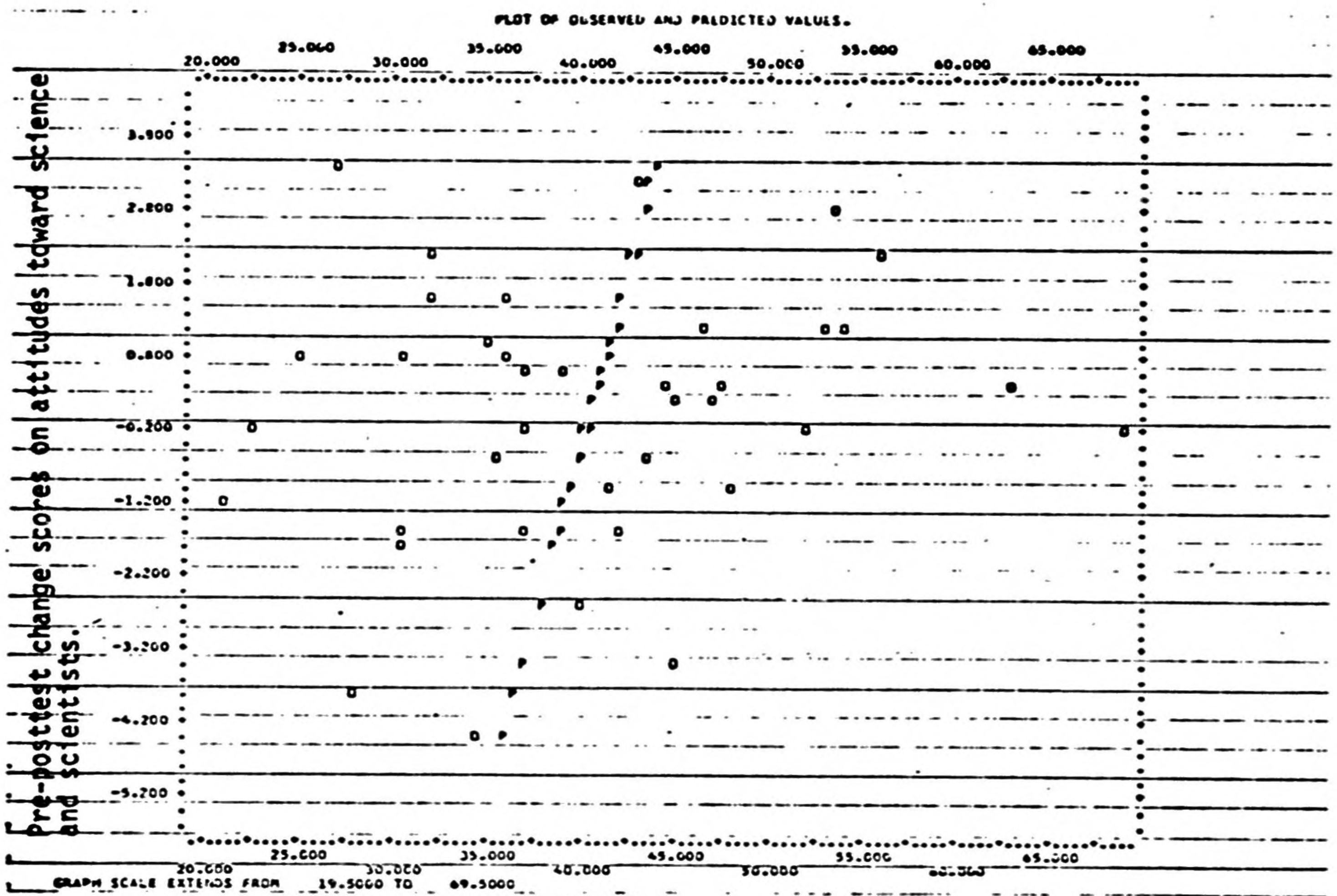


FIGURE 6

I/D Scores

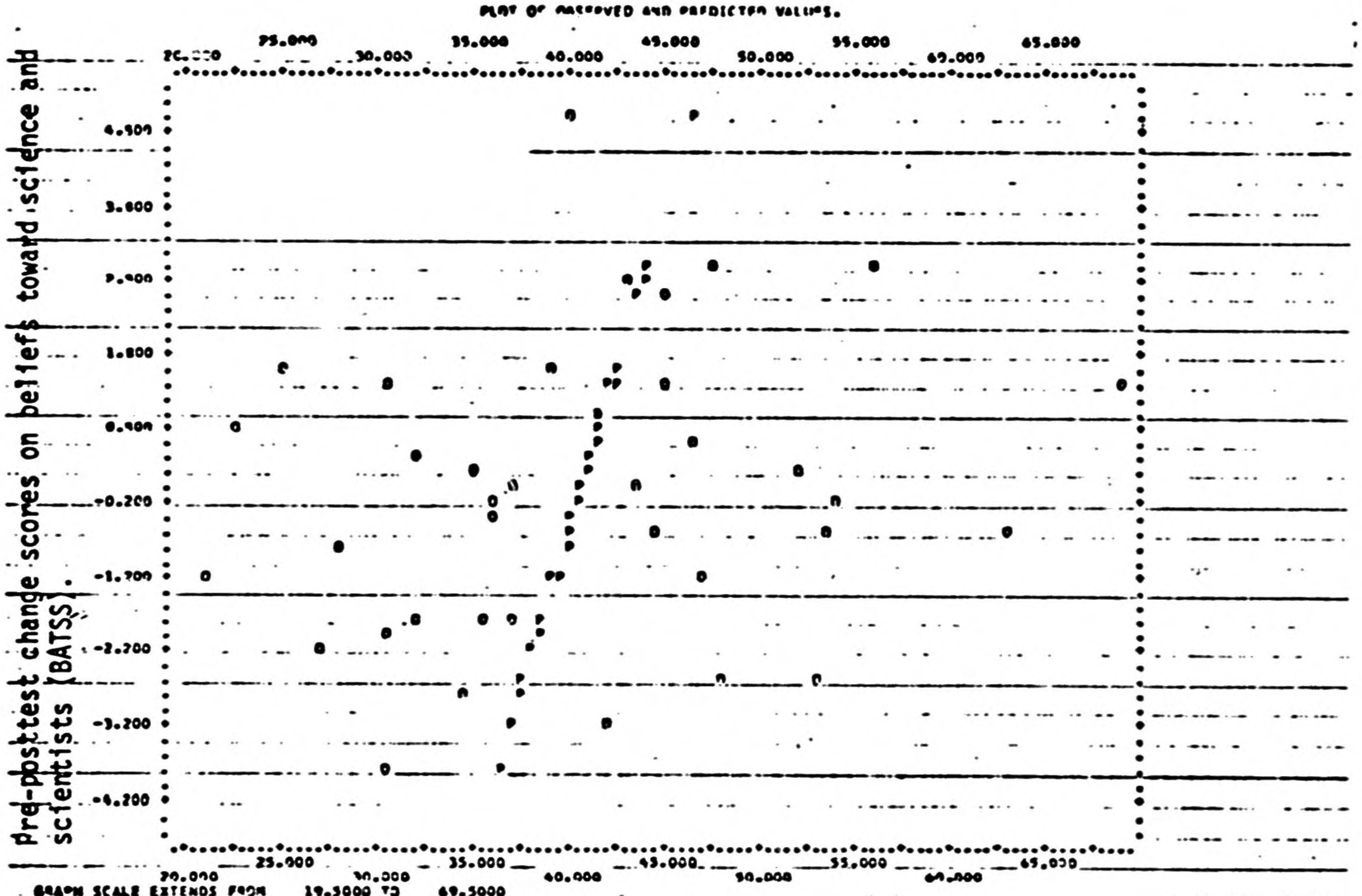
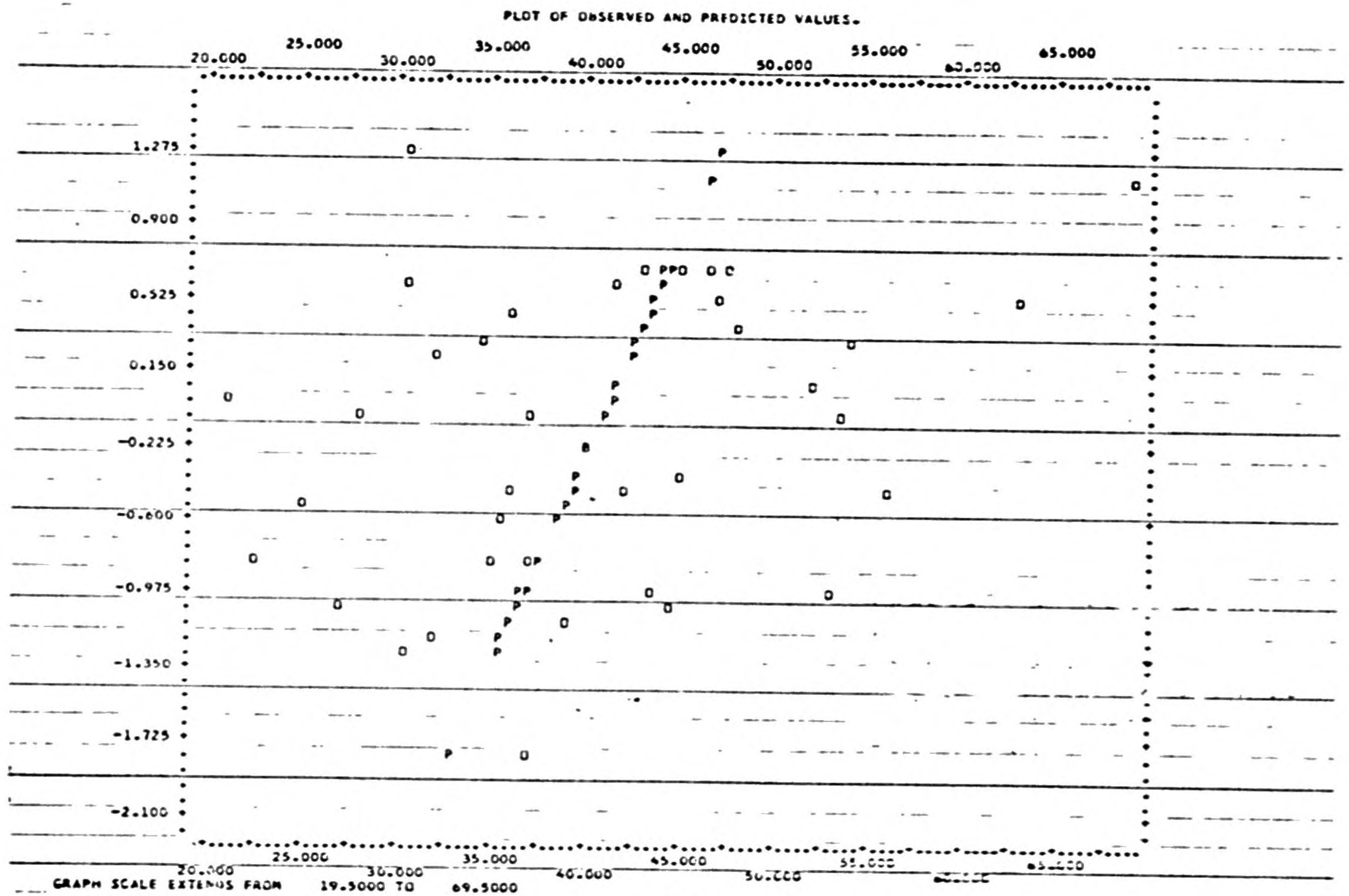


FIGURE 7

I/D Scores



Pre-posttest change cores on Silance and Remmers Interest Inventory.

FIGURE 8

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